Virginia Department of Environmental Quality

Watershed Assessment for Kits Creek – Benthic Impairment

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1.0 Introduction

Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations[1] require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA, 1991).

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS) to account for any uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. The TMDL components are illustrated using the following equation:

$$\text{TMDL} = \Sigma\, WLAs + \Sigma\, LAs + MOS$$

The development of a TMDL for water bodies impaired for aquatic life use (due to poor health in the benthic biological community) requires a methodology that identifies the specific causes of the impairment and determines pollutant reductions for a stream to attain its designated use in compliance with Virginia's Water Quality Standards (9 VAC 25-260). The first step in identifying the causes of the impairment is the identification of the pollutant(s), or stressor(s), responsible for the impaired biological community.

Chapter 1 of this report presents the regulatory guidance and defines the applicable water quality criteria for biological impairment. Chapter 2 characterizes the watershed and Chapter 3 describes environmental monitoring data collected on Kits Creek. Stressors which may be impacting the benthic community of Kits Creek are analyzed in Chapter 4

[1] Codified at Title 40 of the Code of Federal Regulations [CFR] Part 130.

(Stressor Identification Analysis). Based on this analysis, potential stressors impacting benthic macroinvertebrate communities in the creek are identified.

1.1 Regulatory Framework

As stated above, CWA Section 303(d) USEPA's Water Quality Planning and Management Regulations require states to TMDLs for water bodies that do not meet water quality standards. The Virginia Department of Environmental Quality (VADEQ) is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. VADEQ works in coordination with the Virginia Department of Conservation and Recreation (VADCR), the Department of Mines, Minerals, and Energy (VADMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. VADEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning and Management Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997. VADEQ also coordinates public participation throughout the TMDL development process.

Until June 2013, a primary role of VADCR within the context of the TMDL program was to regulate stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the Virginia Stormwater Management Program (VSMP). As of July 2013, these two stormwater regulatory programs are administered by VADEQ. VADEQ also manages the important role of initiating non-point source pollution control programs statewide through the use of federal grant money. VADMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for bacteria, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (VADEQ, 2000).

As required by the 1972 CWA and WQMIRA (VADEQ, 2000), VADEQ develops and maintains a list of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters (303(d) List). TMDLs are developed for streams on this list. Once TMDLs have been developed, they are distributed for public comment and then submitted to the State Water Control Board (SWCB) and USEPA for approval.

1.2 Impairment Listing

Segment VAC-K02R_KIT01A06 of Kits Creek was first listed as benthic impaired on Virginia's 2008 303(d) TMDL Priority List and Report (VADEQ, 2010) due to poor health in the benthic biological community. This report describes the severity and need for TMDLs on surface waters in Virginia based on conditions from 2001 through 2006. This segment was also included on subsequent Virginia 303(d) Reports on Impaired Waters and Virginia 305(b)/303(d) Water Quality Integrated Assessments (VADEQ, 2011; 2013). Kits Creek is located in the central region of Virginia, within Lunenburg County, and empties into the North Meherrin River (Hydrologic Unit Code [HUC] 03010204). VADEQ has recently moved towards a more cost effective approach to conducting TMDLs. This report will summarize the potential and most probable stressors and determine if a TMDL is the most appropriate course of action after the conclusion of the stressor analysis.

Based on monitoring data for the 2012 Water Quality Assessment (2005 through 2010) at station 5AKIT002.65, Kits Creek was found not to be supporting the standard of propagation and growth of aquatic life (**Table 1-1**).

Table 1-1: Impairment Summary for Kits Creek (VAC-K02R-03-BEN)

Cause Group Code	Assessment Unit	Stream Name	Length (miles)	Boundaries	Listing Station	Impairment for
K02R-03-BEN	VAC-K02R_KIT01A06	Kits Creek	4.72	Kits Creek from its headwaters to the mouth	5AKIT002.65	Benthic Macro-invertebrates

1.3 Applicable Water Quality Standard

Water quality standards include designated uses for a waterbody and criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term 'water quality standards' is defined as:

> *"…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect public health or welfare, enhance the quality of water, and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"…all state waters, are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

Based on the biological assessment surveys conducted on the stream, the listed segment of Kits Creek defined in Section 1.2 do not support the propagation and growth of aquatic life.

1.3.2 Water Quality Criteria

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. The General Standard states:

> *"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations,*

> *amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

The biological assessments conducted on Kits Creek between 2004 and 2013 indicated that some pollutant(s) are interfering with attainment of the General Standard, as impaired macroinvertebrate communities have been observed in the listed segment of the stream. Although biological assessments are indicative of the impacts of pollution, the specific pollutant(s) and source(s) are not necessarily known based on biological assessments alone.

2.0 Watershed Characterization

The physical conditions of Kits Creek watershed were characterized using geographic information system (GIS) coverage to provide an overview of the conditions in the watershed related to the benthic impairment in Kits Creek. Physical watershed features such as topography, soil types, and land use conditions were characterized. There are no permitted facilities within this watershed. This chapter provides an inventory of the existing conditions in the watershed that were considered during the stressor analysis.

2.1 Watershed Location and Boundary

Kits Creek watershed is located entirely within Lunenburg County in the central region of Virginia. The watershed is located within the Reedy Creek-North Meherrin River watershed HUC 030102040204). This HUC, along with a digital elevation model (DEM) (Section 2.3) were the basis for the delineation of Kits Creek watershed. The impaired benthic segment of Kits Creek (K02R-03-BEN) is 4.72 miles in length, and the watershed boundary extends from the headwaters downstream to the confluence with the North Meherrin River (**Figure 2-1**). The watershed is approximately 3,009 acres (7.4 square miles) in area and is bordered by the Big Juniper Creek watershed to the north and the Middle Meherrin River watershed to the southwest.

2.2 Stream Network

The stream network for the Kits Creek watershed was obtained from the USGS National Hydrography Dataset (USGS, 2010). The stream network and benthic impairment segment are presented in **Figure 2-1**.

2.3 Topography

A DEM based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the USGS Seamless Data Distribution System (USGS, 2010). The DEM show that the elevation in the watershed ranges from about 298 to 551 feet above mean sea level. The stream drops 0.8 feet in elevation per 100 feet of stream, indicating the slope of watercourse is relatively flat.

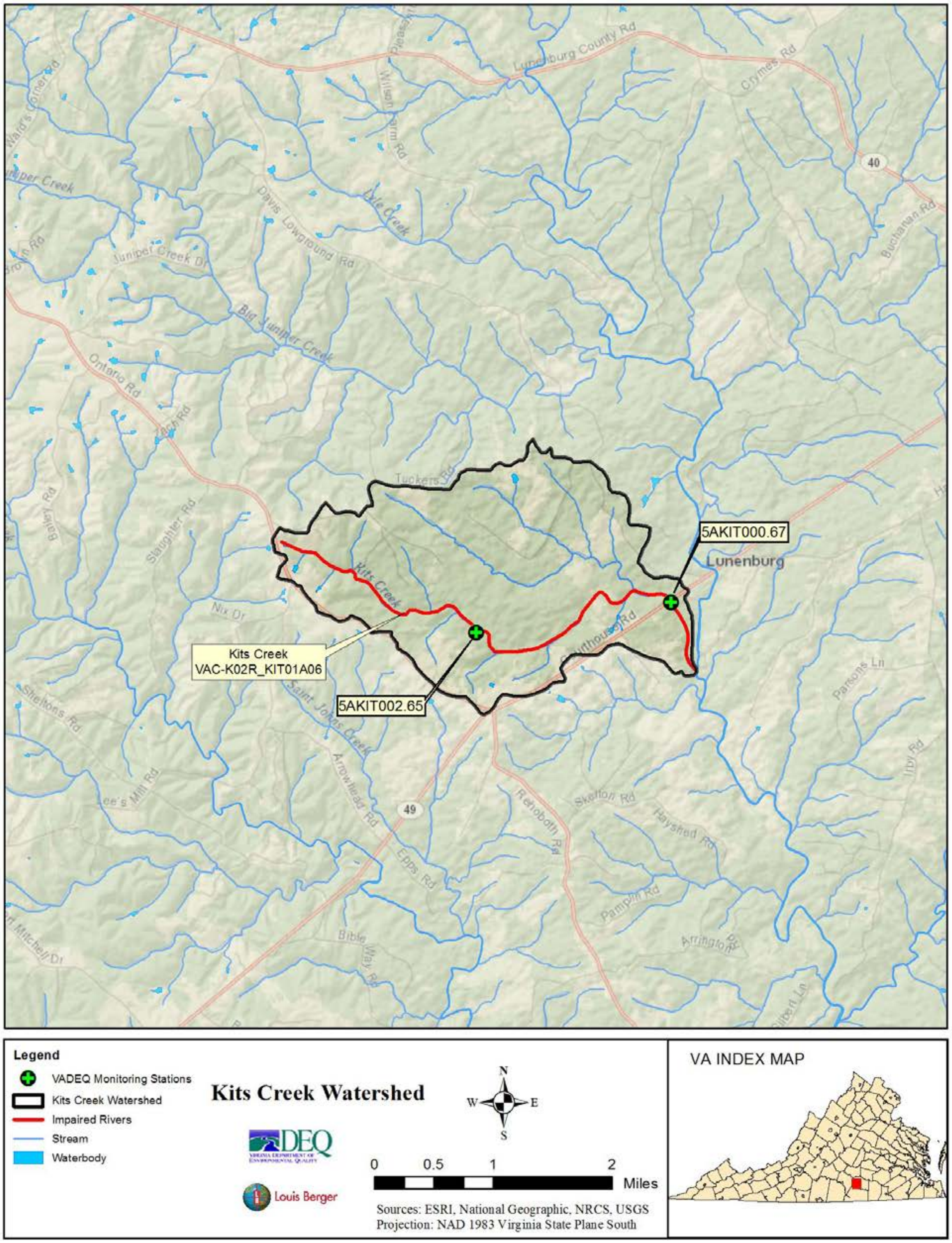

Figure 2- 1: Stream Network and Benthic Impairment for the Kits Creek Watershed

2.4 Soils

This section describes soil types and hydrologic groups for the Kits Creek watershed. The soil type characterization is based on the Soil Survey Geographic (SSURGO) database via the *Web Soil Survey*, a USDA program that is a multi-purpose environmental analysis system integrating GIS, national watershed data, and environmental assessment and modeling tools (NRCS, 2006). There are 23 soil types located in the watershed (**Table 2-1**). The dominant soil types within the watershed are Georgeville loam (2-7% slopes, eroded) with 37.7%, and Tatum loam (15-30% slopes, eroded) with 15.7%.

Table 2-1: Soil Types in Kits Creek Watershed

Soil type	Percent of Watershed
Appling sandy loam, 2 to 7 percent slopes, eroded	1.0%
Appling sandy loam, 7 to 15 percent slopes, eroded	1.2%
Caroline sandy loam, 1 to 7 percent slopes	0.3%
Cecil sandy loam, 2 to 7 percent slopes, eroded	0.5%
Chewacla, Toccoa, and Augusta loams, frequently flooded	6.1%
Georgeville loam, 2 to 7 percent slopes, eroded	37.7%
Georgeville loam, 7 to 15 percent slopes, eroded	9.9%
Goldston channery loam, 15 to 45 percent slopes	0.7%
Helena sandy loam, 1 to 6 percent slopes	0.4%
Helena sandy loam, 6 to 10 percent slopes, eroded	0.1%
Herndon loam, 2 to 7 percent slopes, eroded	2.3%
Herndon loam, 7 to 15 percent slopes, eroded	7.1%
Iredell loam, 1 to 6 percent slopes	3.7%
Iredell loam, 6 to 12 percent slopes, eroded	1.3%
Lignum loam, 6 to 10 percent slopes, eroded	0.3%
Mecklenburg loam, 15 to 20 percent slopes, eroded	3.4%
Mecklenburg loam, 2 to 7 percent slopes, eroded	1.0%
Mecklenburg loam, 7 to 15 percent slopes, eroded	1.1%
Nason loam, 15 to 25 percent slopes, eroded	5.9%
Poindexter silt loam, 15 to 25 percent slopes	0.3%
Poindexter silt loam, 25 to 45 percent slopes	0.0%
Tatum loam, 15 to 30 percent slopes, eroded	15.7%
Total	**100.0%**

The hydrologic soil groups are also based on data obtained from the *Web Soil Survey*. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well- to excessively well-drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. Soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water and more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-2**. The term "blank" in the hydrologic group breakdown refers to those classes defined as water areas.

Table 2-2: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well-drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well- and well-drained soils with moderately coarse textures.
B/D	Combination of Hydrologic Soil Groups B and D.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
C/D	Combination of Hydrologic Soil Groups C and D.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover.

The major hydrologic group within the Kits Creek watershed is group B, with 65.6% of the watershed containing these soils. Soil hydrologic group B is defined as having moderate infiltration rates. Soils are moderately deep to deep, moderately well- to well-drained soils with moderately coarse textures. Soil hydrologic groups D, 16.6%, make up the second-largest portion of the watershed. Soil group D is defined as having very slow infiltration rates. **Table 2-3** summarizes the total percentages of hydrologic groups for the Kits Creek watershed.

Table 2-3: Soil Hydrogroups in the Kits Creek Watershed	
Soil Hydrogroup	**Percent of Watershed**
B	65.6%
B/D	6.1%
C	6.5%
C/D	4.9%
D	16.6%
Blank (water)	0.2%
Total	**100.0%**

Data obtained from the *Web Soil Survey* also contain information about the potential for soil erosional hazard of forest roads and trails. Each soil type was assigned a category for its potential to erode due to mentioned activities on a scale from slight to severe (**Table 2-4)**. Almost 94% of the watershed's soils have a moderate or severe potential for erosion. This is consistent with the soil types in the watershed (**Table 2-1**); 15 of the 23 soil types have "eroded" in their map unit descriptions.

Table 2-4: Soil Potential Erosional Hazard (Forest Roads and Trails)	
Potential for Erosion	**Percent of Total**
Slight	6.1%
Moderate	47.2%
Severe	46.5%
Not Rated (water)	0.2%
Total	**100.0%**

2.5 Land Use

The land use characterization for the Kits Creek watershed was based on the 2011 National Land Cover Database (Homer et al., 2015). The land uses in the watershed, by land area and percentage, are presented in **Table 2-5** and **Figure 2-2**. Dominant land uses are forest and agriculture (primarily pasture/hay/grassland).

Table 2-5: Land Use in the Kits Creek Watershed

General Land Use Category	NLCD 2006 Land Use Category	Acres	Percentage of Watershed	Total Acres	Total Percent
Developed	Developed Low Intensity	0.5	0.02%	65.9	2%
	Developed Open Space	65.4	2.17%		
Agricultural	Cultivated Crops	22.5	0.75%	519.0	17%
	Pasture/Hay	291.3	9.68%		
	Grassland/Herbaceous	205.3	6.82%		
Forest	Deciduous Forest	1,101.1	36.60%	2,032.9	68%
	Evergreen Forest	680.6	22.62%		
	Mixed Forest	251.2	8.35%		
Water & Wetlands	Open Water	1.1	0.04%	52.5	2%
	Emergent Herbaceous Wetlands	1.3	0.04%		
	Woody Wetlands	50.0	1.66%		
Other	Scrub/Shrub	330.1	10.97%	338.3	11%
	Barren Land	8.2	0.27%		
	Total	**3,008.6**	**100.00%**	**3,008.6**	**100%**

2.6 Ecoregion Classification

The Kits Creek watershed is located in the Piedmont ecoregion, USEPA Level III classification number 45 (Woods et al., 1996). The Piedmont ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia, and forms a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the flat coastal plain to the southeast. Once largely cultivated, much of this region has reverted to pine and hardwood woodlands. The Piedmont ecoregion is characterized by shallow valleys, irregular plains, and low rounded hills and ridges. The underlying geology of this region consists of deeply weathered, deformed metamorphic rocks with intrusions by igneous material.

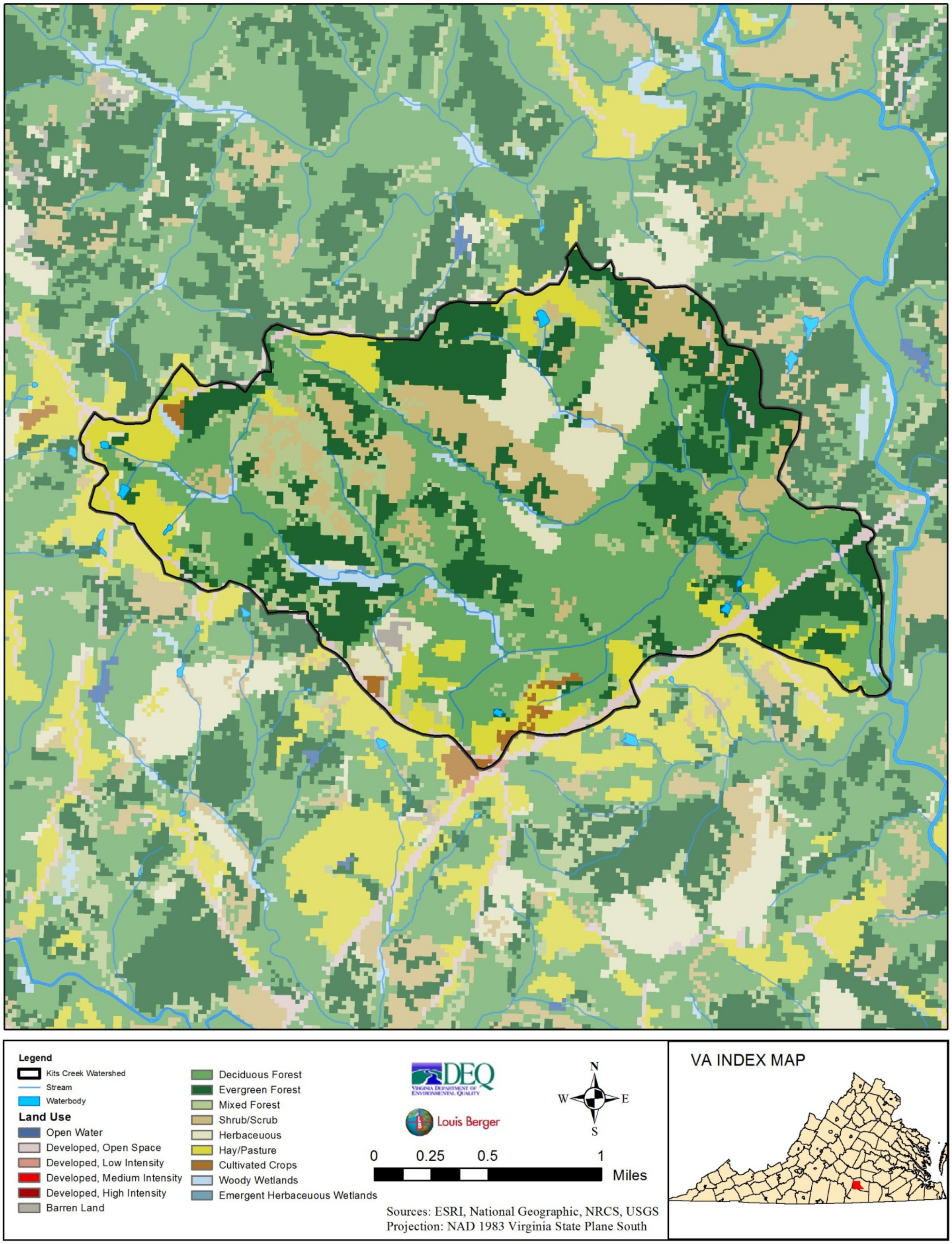

Figure 2- 2: Land Use in the Kits Creek Watershed

3.0 Environmental Monitoring

Environmental monitoring efforts in the Kits Creek watershed include benthic community sampling and analysis, habitat condition assessments, ambient water quality sampling, and sediment metals sampling. Monitoring efforts presented in this chapter were conducted by VADEQ.

3.1 DEQ Monitoring Stations

VADEQ has monitored ambient water quality, macroinvertebrate communities and sediment chemistry at two locations in the Kits Creek watershed. A list of the VADEQ monitoring stations in the Kits Creek watershed is provided in **Table 3-1**; station locations are included in **Figure 2-1**. Station identification numbers include the abbreviated creek name and the river mile on the creek where the station is located (the river mile number represents the distance from the mouth of the creek). Station 5AKIT002.65 is part of VADEQ's freshwater probabilistic monitoring program for the 2012 Integrated Assessment (VADEQ, 2013). Probabilistic monitoring is designed to answer questions about statewide and regional water quality conditions. The program has evaluated over 700 sites statewide since the program began in 2001. Because of the inclusion of station 5AKIT002.65 in the probabilistic monitoring program, additional data such as instream metals and sediment metals and organics were collected, in comparison to a typical ambient monitoring station such as 5AKIT000.67.

Table 3-1: Kits Creek Monitoring Stations

Station	Available Data	Sampling Dates		Count
		Start	End	
5AKIT000.67	Instream chemical parameters	1/24/2013	12/19/2013	13
5AKIT002.65	Macroinvertebrates	5/25/2004	9/30/2013	8
	Instream chemical parameters	5/25/2004	9/30/2013	7
	Instream metals	5/25/2004	4/16/2013	4
	Sediment Metals and Organics	5/25/2004	5/3/2011	3

3.2 Biological Monitoring Data

Based on biological monitoring data, Kits Creek was originally listed as impaired on the 2008 303(d) list for not meeting the aquatic life use due to poor health in the benthic biological community. Kits Creek was subsequently listed in the 2010 and 2012 Integrated 305(b)/303(d) Assessments. Biological monitoring data were collected at station 5AKIT002.65 during the spring and fall of 2004, 2005, 2011, and 2013. Biological monitoring data were evaluated using the Virginia Stream Condition Index (VSCI). Calculation of a VSCI score incorporates eight standard metrics based on the abundance and types of macroinvertebrates present at each station. The multiple metrics evaluated together give an overall indication of ecological integrity. These VSCI metrics were compared to a reference condition, which is based on an aggregate of unimpaired streams in non-coastal Virginia. The VSCI metrics and their expected response to declining stream conditions are presented in **Table 3-2**.

Table 3-2: Metrics Used to Calculate the Virginia Stream Condition Index (VSCI)*

Metrics	Expected Response to Disturbance	Definition of Metric
Taxonomic Richness		
Total Taxa	Decrease	Total number of Taxa observed
EPT Taxa	Decrease	Total number of pollution sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa observed
Taxonomic Composition		
% PT Less Hydropsychidae	Decrease	% PT taxa in samples, subtracting pollution-tolerant Hydropsychidae
% Ephemeroptera	Decrease	% Ephemeroptera taxa present in sample
% Chironomidae	Increase	% pollution-tolerant Chironomidae present
Balance/Diversity		
% Top 2 Dominant	Increase	% dominance of the two most abundant taxa
Tolerance		
HBI (Family level)	Increase	Hilsenhoff Biotic Index (HBI)
Trophic Group		
% Scrapers	Decrease	% of scraper functional feeding group

* Source: Burton and Gerritsen, 2003

An impairment cutoff score of 60.0 is used for assessing results. Stream segments that have a VSCI score of 60 or greater are generally considered to be non-impaired, while streams that score less than 60 are generally considered impaired (VADEQ, 2013).

VSCI Metrics

In the Kits Creek watershed, VSCI scores were calculated for 5AKIT002.65. A total of eight benthic sampling events occurred between 2004 and 2013. The following is a summary of the metrics used in calculating the VSCI scores.

- ***Taxonomic Richness.*** Taxa richness measures the overall variety of the invertebrate assemblage by counting the number of distinct taxa within selected taxonomic groups (Burton and Gerritsen, 2003). High taxa richness is usually an indicator of a healthy benthic community. At the Kits Creek watershed monitoring station, the total taxa ranged from 9 to 16, and averaged 11.

  Another metric of taxonomic richness is the EPT (Ephemeroptera - mayflies, Plecoptera - stoneflies, Trichoptera - caddisflies) index. The EPT index is the number of families from the EPT orders in a sampling. Since the majority of the families in the EPT orders are intolerant of pollution and other environmental stressors, the EPT index is another indicator of benthic community health. EPT Taxa were consistently lower than total taxa across all sampling periods and ranged from 3 to 6 taxa, averaging 4 taxa. **Figure 3-1** presents the total taxa and EPT taxa data collected from 2004 to 2013.

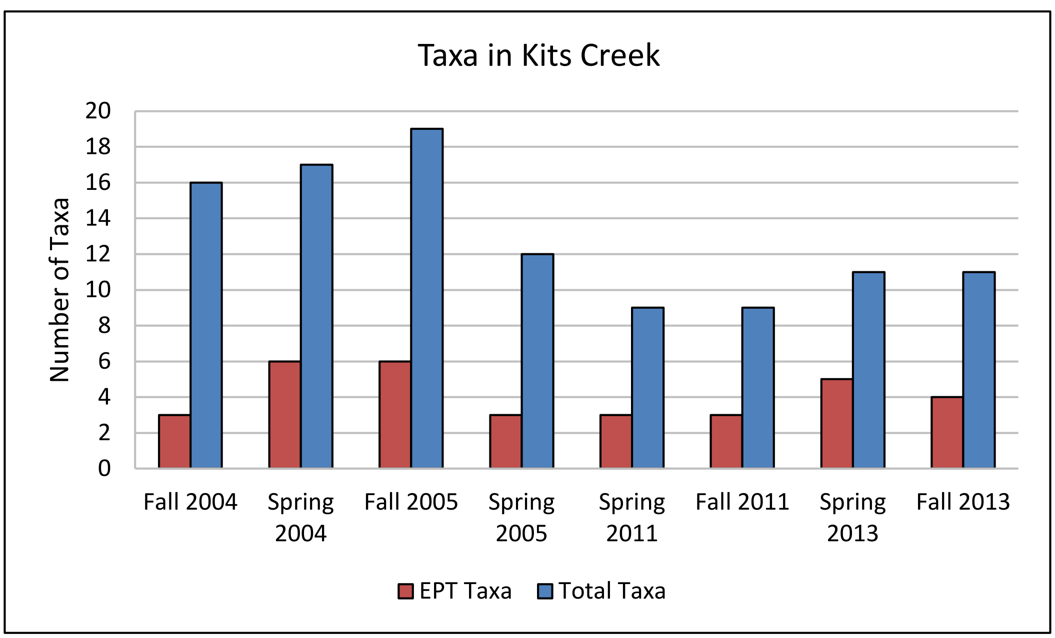

Figure 3-1: Total Taxa and EPT Taxa in the Kits Creek Watershed

- ***Taxonomic Composition***. The composition of stoneflies and caddisflies (Plecoptera and Trichoptera, respectively), excluding the family of netspinning caddisflies (Hydropsychidae) that are pollution-tolerant, were measured as an indicator of stream health. The percent PT (less Hydropsychidae) ranged from 1 to 20%, averaging 6%. The percent composition of mayflies (Ephemeroptera) was calculated since the majority of these species are highly sensitive to pollution and environmental stress, thus this metric is used as an indicator of stream health. The percent composition of mayflies ranged from 1 to 31%, averaging 11%. The percent composition of midges (Chironomidae) was calculated because midge larvae are tolerant to many stressors, thus this metric is expected to increase with increasing pollution and environmental stress. The percent composition of midges in all samples was high, ranging from 35 to 73%. Figure 3-2 presents the percent composition of stoneflies and intolerant caddisflies, mayfly nymphs, and midge larvae in Kits Creek.

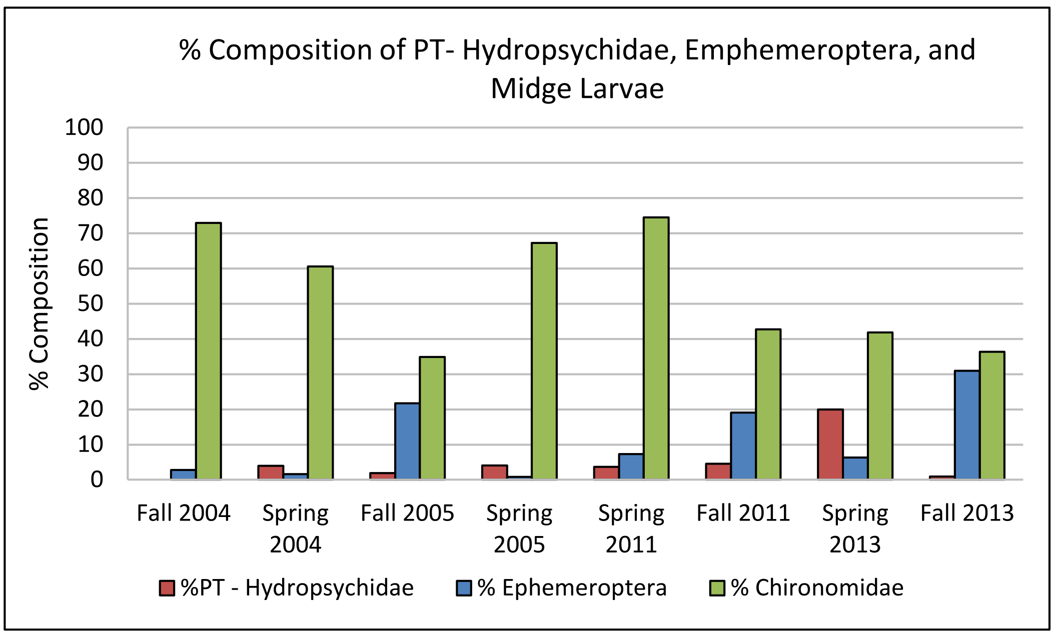

Figure 3-2: Percent Composition of Stoneflies and Intolerant Caddisflies, Mayfly Nymphs, and Midge Larvae in the Kits Creek Watershed

- ***Balance and Diversity***. The percentage of the two most abundant taxa was calculated as a measure of the community balance within the sample. As with taxa richness, a community in a polluted stream will most often be dominated by a few taxa. The Kits Creek watershed samples from all periods were dominated by two taxa. Figure 3-3 presents the percent composition of the two most dominant taxa in Kits Creek.

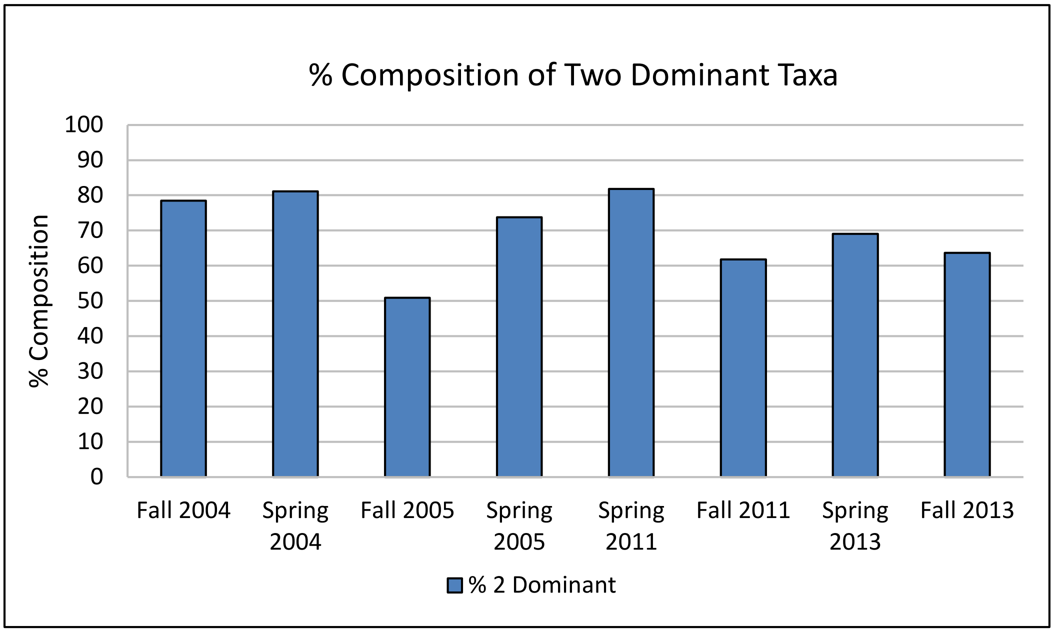

Figure 3-3: Percent Composition of Two Most Abundant Taxa in the Kits Creek Watershed

- ***Tolerance***. The Hilsenhoff's Biotic Index (HBI) was calculated as a measure of a macroinvertebrate community's tolerance to pollution. HBI scoring is on a scale from zero to ten, with zero indicating unpolluted conditions. In Kits Creek, most samples were above 5.0, indicating some to fairy significant organic pollution (Zimmerman, 1993). **Figure 3-4** presents the HBI scores for Kits Creek.

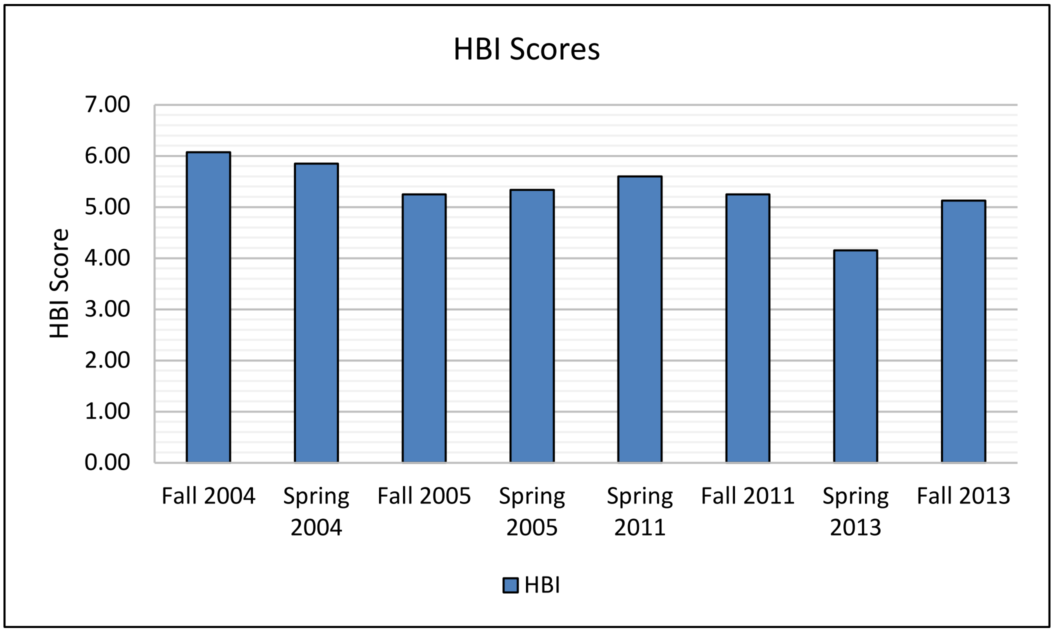

Figure 3-4: HBI Scores in the Kits Creek Watershed

- ***Trophic Group***. Some macroinvertebrates feed by scraping the thin layer of periphyton at the surface of stream substrata. The abundance of scrapers tends to increase with increased diatom and other algal abundance, and decrease as macrophytes, mosses, and blue-green algae accumulate. High levels of sediment, and organic or nutrient pollution causes declines in scraper numbers. Increased sediment loads tend to limit the production of periphyton which, in turn, decreases the available food sources for scrapers. Alternatively, increases in organic or nutrient pollution can cause an accumulation of algae and mosses. In Kits Creek, the average percent of scrapers was 12%. In looking at the data on nutrients, the low percentage of scrapers could indicate nutrient pollution is a stressor to the benthic community. **Figure 3-5** presents the percent composition of scrapers in Kits Creek.

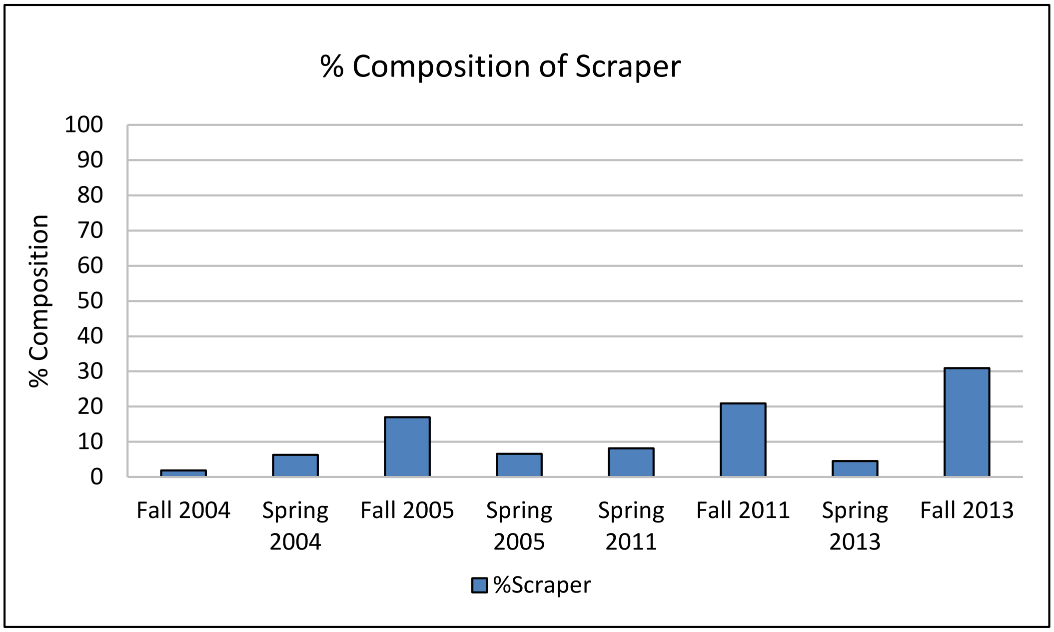

Figure 3-5: Percent Composition of Scrapers in the Kits Creek Watershed

VSCI Results. The data discussed in the sections above were included by VADEQ in calculating the VSCI scores for the station 5AKIT002.56. **Table 3-3** and **Figure 3-6** shows the VSCI score results for station 5AKIT002.56. The optimal conditions for the benthic community are VSCI scores above 60. Suboptimal conditions are for benthic communities which score below 50. VSCI scores for all samples were below the cutoff value of 60, and only one sample was above 50. On average, the samples had a score of 38.8.

Table 3-3: Virginia SCI Scores for Kits Creek (Station 5AKIT0002.56)

Collection Period	VSCI Score
Fall 2004	28.0
Spring 2004	35.7
Fall 2005	52.6
Spring 2005	30.8
Spring 2011	27.8
Fall 2011	41.9
Spring 2013	45.0
Fall 2013	48.4
Average	**38.8**

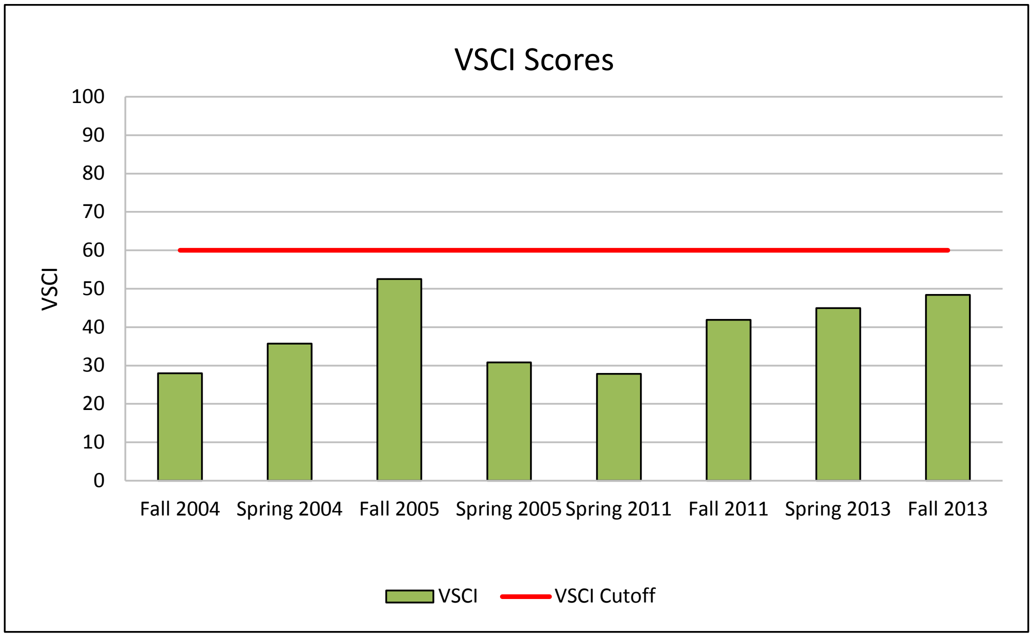

Figure 3-6: VSCI Scores for the Kits Creek Watershed

3.3 Habitat Assessment Scores and Relative Bed Stability

Habitat Assessment Scores

A suite of habitat variables were visually inspected by VADEQ at monitoring stations as part of the biological assessments conducted in the Kits Creek watershed. VADEQ used USEPA's Rapid Bioassessment Protocols (RBP) to qualitatively evaluate the habitat for the benthic community (Barbour et al., 1999). Habitat parameters that were examined included epifaunal substrate, embeddedness, velocity, sedimentation, channel flow, channel alteration, frequency of riffles, bank stability, bank vegetative protection, riparian zone, sinuosity, pool substrate, and pool variability. During each sampling event, parameters were assigned a score from 0 to 20, with 20 indicating optimal conditions, and 0 indicating very poor conditions. Scores between 0 and 5 are deemed poor, scores between 5 and 10 are marginal, scores between 10 and 15 are suboptimal, and scores over 15 are considered optimal (Burton and Gerritsen, 2003). VADEQ assessed habitat scores between 2004 and 2013 in Kits Creek. Habitat assessment scores for the biomonitoring stations in the Kits Creek watershed are presented in **Table 3-4.**

Table 3-4: Kits Creek Habitat Scores (Station 5AKIT0002.56)									
Habitat Metric	**Fall 2004**	**Spring 2004**	**Fall 2005**	**Spring 2005**	**Spring 2011**	**Fall 2011**	**Spring 2013**	**Fall 2013**	**Average**
Epifaunal Substrate	5	12	8	11	11	13	11	10	**10**
Embeddedness	-	-	-	-	18	11	11	7	**12**
Velocity	-	-	-	-	10	15	16	10	**13**
Sediment Deposition	5	13	8	13	13	8	11	7	**10**
Channel flow	15	17	16	14	9	15	9	9	**13**
Channel Alteration	20	20	17	17	20	19	16	17	**18**
Frequency of Riffles					13	16	12	18	**15**
Bank Stability	14	10	10	10	11	16	10	10	**11**
Bank Vegetative Protection	14	16	10	12	11	16	10	14	**13**
Riparian Zone	20	19	16	16	20	18	18	12	**17**
Sinuosity	15	15	11	11	-	-	-	-	**13**
Pool Substrate	8	13	13	7	-	-	-	-	**10**
Pool Variability	3	10	9	13	-	-	-	-	**9**
Total Habitat Score	**119**	**145**	**118**	**124**	**136**	**147**	**124**	**114**	**128**

The total habitat scores in the Kits Creek watershed ranged between 114 and 147 with an average score of 128. In looking at the probabilistic monitoring threshold conditions, habitat scores below 120 indicate suboptimal conditions for the benthic community, and scores above 150 indicate optimal conditions. In Kits Creek, no habitat scores are in the optimal risk category, and the score of two of the eight samples is below 120. While all scores are relevant, scores for habitat metrics such as epifaunal substrate, embeddedness, sediment deposition, and bank stability, are of particular importance to determine if instream habitat degradation is contributing to the decline in the health of the benthic community. The following is a summary of some of the habitat metrics for Kits Creek watershed:

- The epifaunal substrate metric is a measure of the relative quantity and variety of natural structures in the stream for spawning and nursery functions of aquatic macrofauna. In the Kits Creek watershed, scores ranged between 5 and 13 with an average score of 10, indicating suboptimal conditions. Scores are consistent throughout sampling events.

- The embeddedness metric is the extent to which rocks and snags are covered or sunken in silt, sand, or mud in the stream bottom. In the Kits Creek watershed, scores ranged between 7 and 18 with an average score of 12, indicating suboptimal conditions. Embeddedness was only measured in the samples from 2011 and 2013. All of the habitat scores, including embeddedness, describe optimal conditions at the higher end of the scale and degraded conditions at the lower end. Although somewhat counterintuitive, a high embeddedness score indicates little to no silt or sand covering the rocks and snags, while a low embeddedness score indicates a greater quantity of silt or sand covering the rocks and snags.

- The sediment deposition metric is the amount of sediment that has accumulated in pools and the changes that have occurred to the stream's bars or islands due to deposition. Lower scores would indicate large-scale movement of sediment is occurring in the stream. Sediment deposition scores ranged from 5 to 13 with an average of 10, indicating suboptimal conditions.

- The bank stability metric is the measure of whether stream banks have eroded or have the potential for erosion. Scores from the samples ranged between 10 and 16 with an average of 11, indicating suboptimal conditions.

- The vegetative protection metric is the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. This parameter provides insight on the ability of the bank to resist erosion as well as instream shading, plant nutrient uptake and control of instream scouring. Vegetative protection scores samples ranged from 10 to 16 with an average of 13, indicating suboptimal conditions.

- Pool substrate is a measure of the bottom substrates found in pools. A stream that supports a variety of substrates in its pools will support a more diverse benthic community. Pool variability is a measure of the mixture of pool types found in the streams according to size and depth. A larger variety of streams will also support a more diverse benthic community. Pool variability and substrate were only collected during the 2004 and 2005 sampling periods. The pool substrate scores ranged from 7 to 13 with an average score of 10, indicating marginal to suboptimal conditions. Pool variability scores ranged from 3 to 13 with an average of 9, indicating marginal pool variability within Kits Creek.

Metrics that met the optimal condition range were channel alteration (indicating very little alteration), riparian zone (indicating a healthy buffer between other human land use activities), and frequency of riffles (habitat for certain benthic macroinvertebrates).

Table 3-5 presents the notes listed in VADEQ's 2012 Integrated 305(b)/303(d) Assessment pertaining to Kits Creek (VADEQ, 2013).

Table 3-5: 2012 Integrated Assessment Factsheet Notes

Station	Assessment Period	Assessor Notes
5AKIT000.67	2012	Kits Creek exhibits high seasonal variability. Further sampling is required to accurately characterize water quality within the reach. Spring taxa are dominated by the filtering functional feeding groups (FFG) while fall taxa are more evenly distributed.
5AKIT002.65	2004-2005 Probabilistic Monitoring	Limited instream habitat consisted of riffles dominated by bedrock. Excellent riparian zone.
	2011 Biological Notes	Reach may be subject to storm scour due to prevalence of bedrock substrate.

Relative Bed Stability

Relative Bed Stability (RBS) is a quantitative measure of "stream power" or relative bed particle mobility. A stream with Log Relative Bed Stability (LRBS) of less than -1 is carrying excess sediment while streams above -0.5 have a normal sediment load (Kaufmann, 2007). **Table 3-6** shows the results of the Relative Bed Stability analysis.

Table 3-6: Relative Bed Stability of Kits Creek Monitoring Station 5AKIT002.65

Date	Log Relative Bed Stability
10/5/2004	-0.956
11/8/2005	-0.407
6/8/2009	-0.093
11/7/2011	-0.478
9/30/2012	-0.327

Of the five total relative bed stability measurements, only one sample (Fall 2004) came close to the threshold of -1. The remaining samples were above -0.5, indicating a normal sediment load in Kits Creek.

3.4 Ambient Water Quality Monitoring

VADEQ monitored the water quality at stations located along the benthic impaired segment during the development of the TMDL. **Table 3-7** shows the water quality monitoring stations, the available date range, and maximum number of samples (Count). Water quality monitoring included in-situ measurements (temperature, dissolved oxygen, and pH), and chemical analyses of water samples for nutrients. Samples were compared to the Virginia Water Quality Standards (SWCB, 2011) to determine any water quality degradation. Due to the inclusion of station 5AKIT002.65 in VADEQ's probabilistic monitoring program, instream metals and sediment metals and organics were collected.

Table 3-7: Kits Creek Monitoring Stations

Station	Available Data	Sampling Dates		Count
		Start	End	
5AKIT000.67	Instream chemical parameters	1/24/2013	12/19/2013	13
5AKIT002.65	Instream chemical parameters	5/25/2004	9/30/2013	7
	Instream metals	5/25/2004	4/16/2013	4
	Sediment Metals and Organics	5/25/2004	5/3/2011	3

The instream water quality data within Kits Creek are summarized below.

- ***In-situ Measurements***. Dissolved oxygen concentrations ranged from 5.0 to 14.2 mg/L and were consistently above the minimum regulatory criterion of 4.0 mg/L (**Figure 3-7**). The pH values met VA DEQ's water quality criteria of maintaining pH levels in between 6 to 9 (**Figure 3-8**). The water temperature did not exceed VADEQ criterion of a maximum of 32º Celsius (**Figure 3-9**).

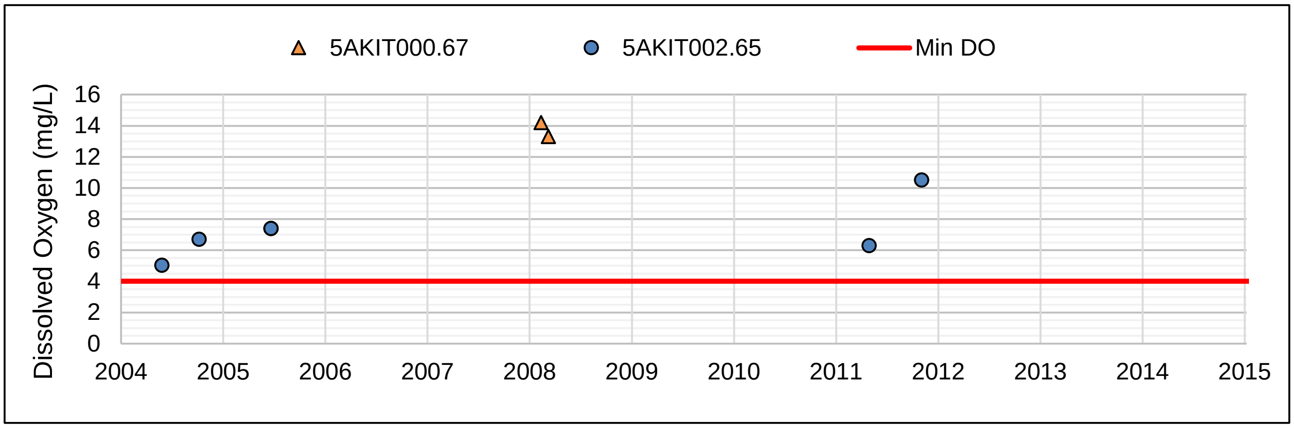

Figure 3-7: Ambient Dissolved Oxygen Measurements in Kits Creek

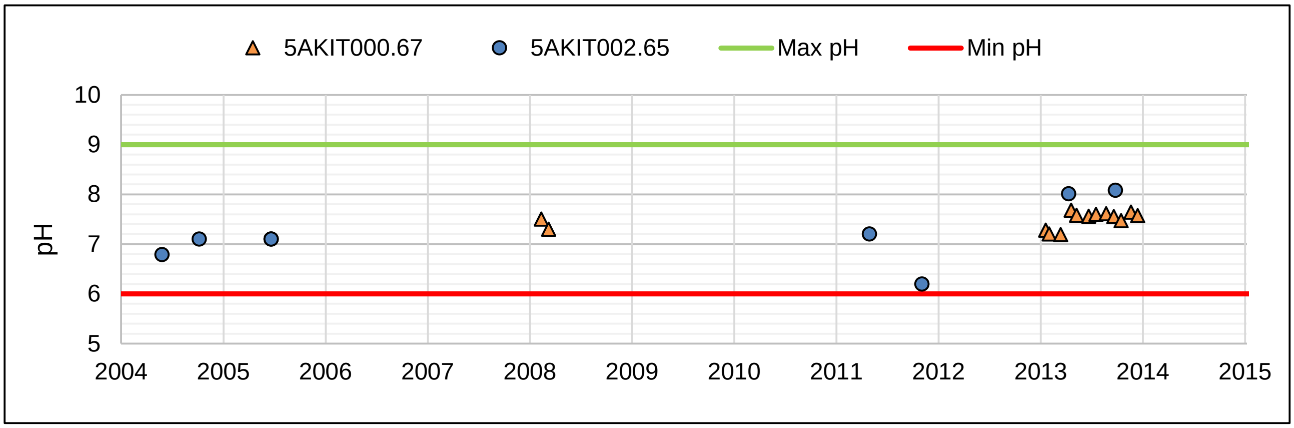

Figure 3-8: Ambient pH Measurements in Kits Creek

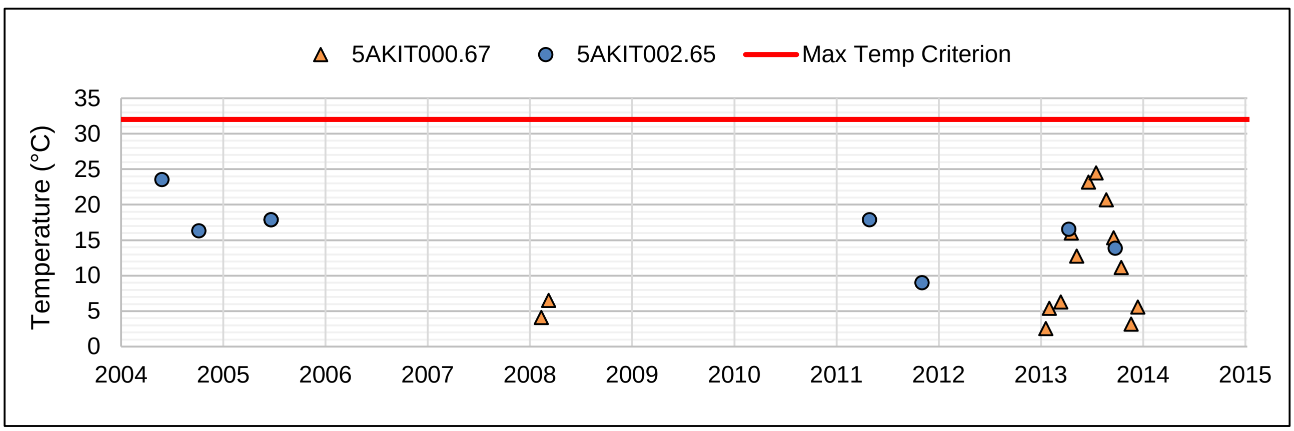

Figure 3-9: Ambient Temperature Measurements in Kits Creek

- ***Nitrogen.***

Total ammonia concentrations did not exceed VADEQ's total ammonia criteria for freshwater when trout are absent. VADEQ ammonia criteria vary with pH, water temperature, and the presence of sensitive fish (trout). Ammonia concentrations in Kits Creek ranged between 0.1 and 1.75 mg/L (**Figure 3-10**). One sample was above the optimal risk to aquatic life category for nitrogen levels in streams (VADEQ, 2013).

Nitrate (NO_3-N) concentrations ranged from 0.08 to 0.98 mg/L. Nitrite (NO_2-N) concentrations ranged between 0.01 and 0.36 mg/L for NO_2-N (**Figures 3-11** and **3-12**). All nitrite and nitrate samples were in the optimal risk to aquatic life category for nitrogen.

Total Kjeldahl Nitrogen (TKN) concentrations ranged between 0.3 and 2.9 mg/L (**Figure 3-13**). Two of the six samples were in the suboptimal risk to aquatic life category for nitrogen.

Total Nitrogen (TN) concentrations ranged between 0.17 and 3.41 mg/L (**Figure 3-14**). Two samples taken at station 5AKIT002.65 were in the suboptimal risk to aquatic life category, and one sample taken at 5AKIT000.67 was above the optimal risk to aquatic life category. It should be noted that the most downstream station (5AKIT000.67) appears to have assimilated some of the high levels of nitrogen measured at station 5AKIT002.65.

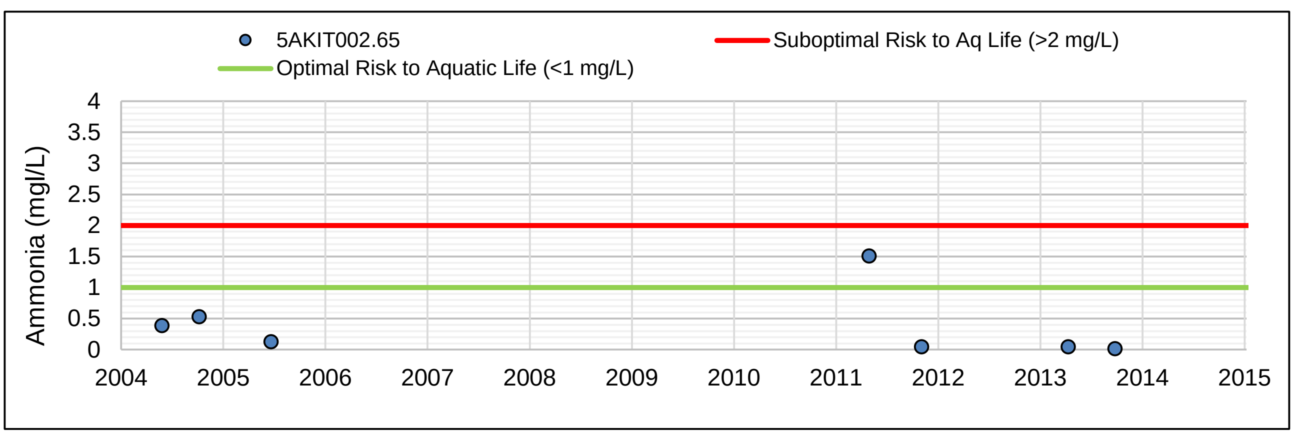

Figure 3-10: Ambient Total Ammonia Measurements in Kits Creek

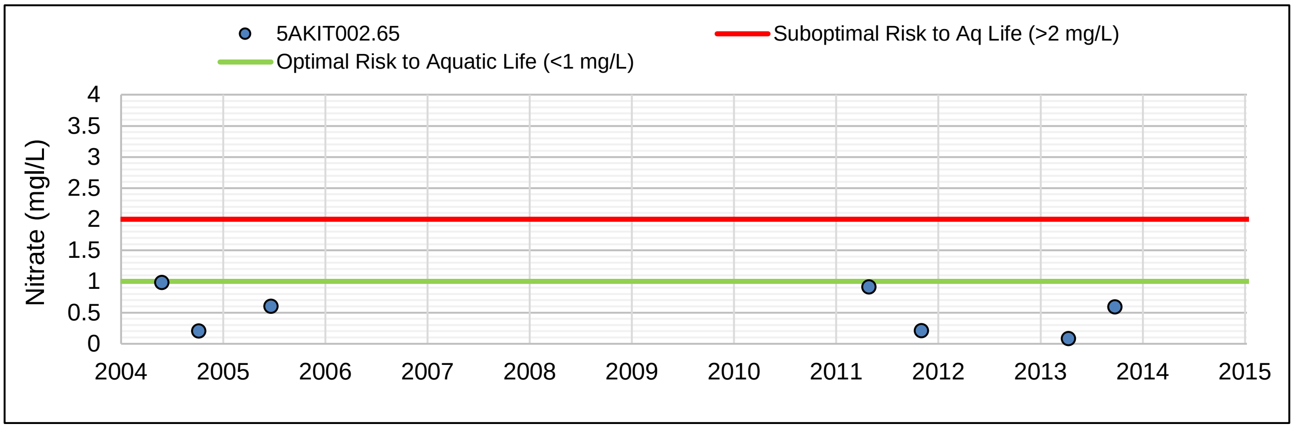

Figure 3-11: Ambient Nitrate Measurements in Kits Creek

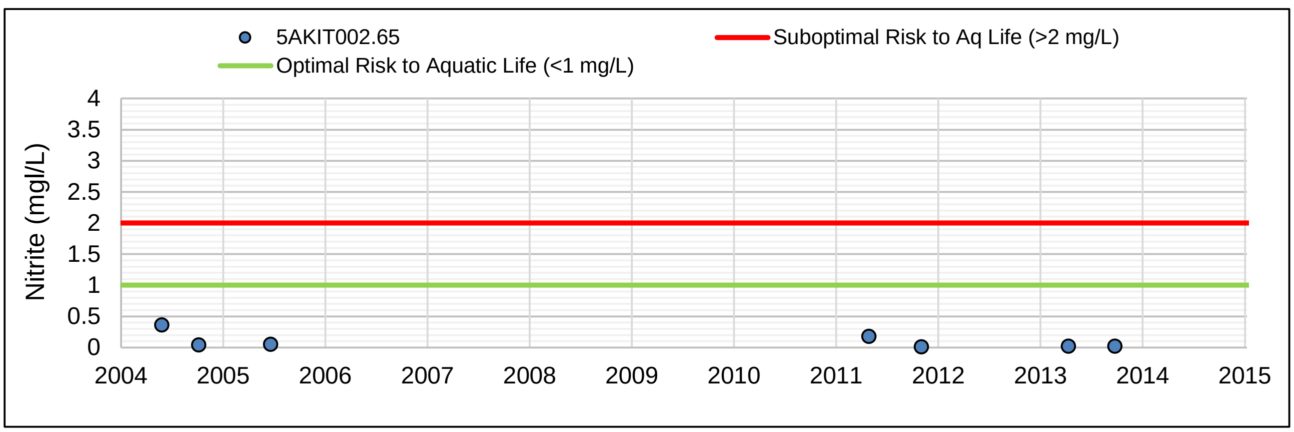

Figure 3-12: Ambient Nitrite Measurements in Kits Creek

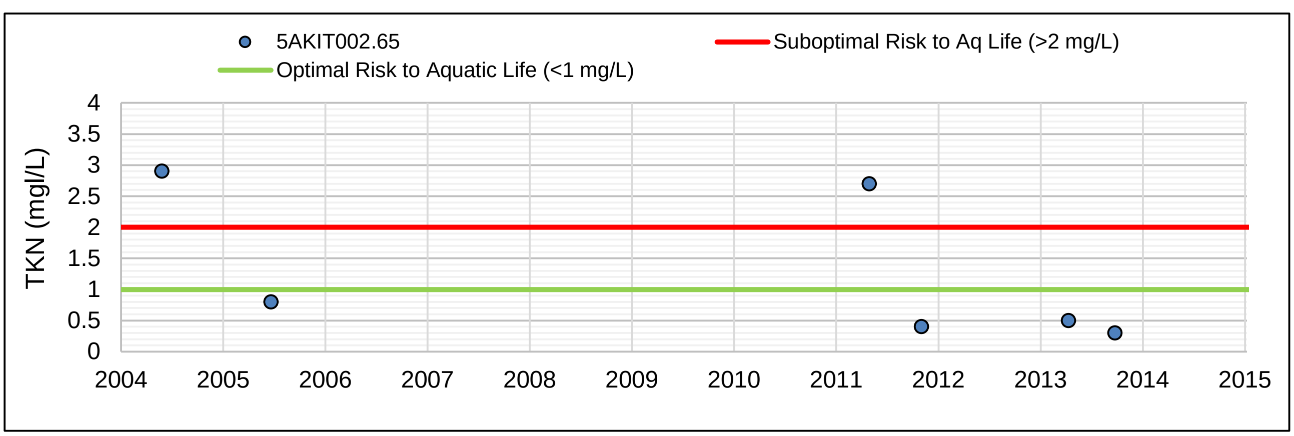

Figure 3-13: Ambient Total Kjeldahl Nitrogen Measurements in Kits Creek

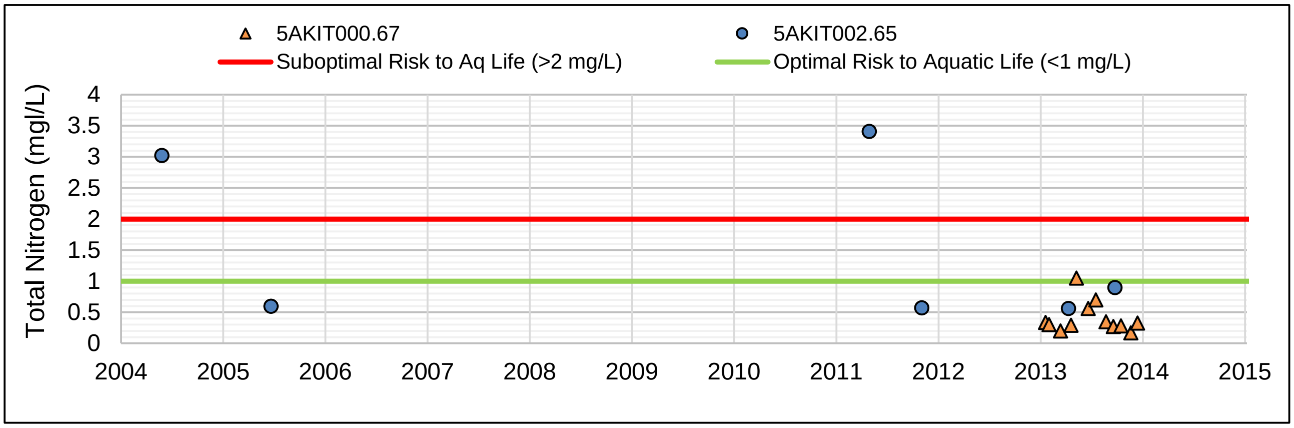

Figure 3-14: Ambient Total Nitrogen Measurements in Kits Creek

- ***Phosphorus.*** Total Phosphorus (TP) concentrations ranged between 0.02 and 3.92 mg/L (**Figure 3-15**). TP concentrations were highest at station 5AKIT002.65 and all samples were above the 0.05 mg/L criterion for suboptimal risk to aquatic life. It is noted that the while most downstream station (5AKIT000.67) appears to have assimilated the high levels of phosphorus measured at station 5AKIT002.65, all of the samples are above the optimal risk to aquatic life criterion of 0.02 mg/L, and two of the samples were above the suboptimal risk to aquatic life criterion (VADEQ, 2013).

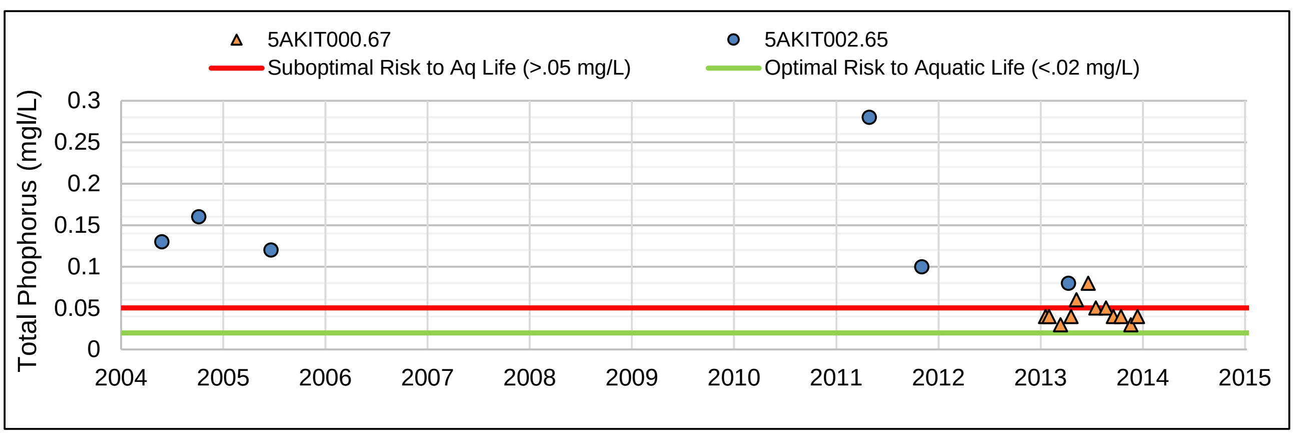

Figure 3-15: Ambient Total Phosphorus Measurements in Kits Creek

- ***Metals***. Water samples from station 5AKIT002.65 were analyzed for dissolved metals (arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc). None of the monitored dissolved metal concentrations exceeded the acute or chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards (SWCB, 2011).

3.5 Sediment Sampling

Sediments were sampled at the probabilistic monitoring station 5AKIT002.65 in 2004, 2005, and 2011 (three samples total). These samples were analyzed for metals and organic compounds.

Metals in sediment were analyzed to determine whether they complied with the screening values known as Probable Effects Concentrations (PECs) for freshwater (VADEQ, 2013). PECs are peer-reviewed, consensus-based sediment quality values above which adverse effects will likely be observed in aquatic organisms (MacDonald et al., 2000). Metals measured in sediment samples included arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. None of the measurements for any metal exceeded the respective PEC value.

Organic compounds (insecticides and pesticides) analyzed in the sediment samples consisted of aldrin, alpha-chlordane, chlorpyrifos, diazinon, dieldrin, endosulfane, endrin, guthion, heptachlor, lindane, malathion, methoxychlor, parathion, and toxaphene None of the compounds with PECs (chlordane, dieldrin, endrin, guthlindane, and heptachlor) exceeded their respective PECs in sediment collected at monitoring station 5AKIT002.65 in 2004 and 2005 (two samples total). Other analyzed compounds did not have PECs to compare to in Virginia.

4.0 Stressor Identification

TMDL development for a benthic impairment requires identification of the pollutant stressor(s) affecting the benthic macroinvertebrate community. Stressor identification for the benthic macroinvertebrate community in the impaired segment of Kits Creek was performed using the available environmental monitoring (up to December 2013) and watershed characterization data, discussed in previous chapters. The stressor identification follows guidelines outlined in the EPA Stressor Identification Guidance (EPA, 2000).

The identification of the most probable cause of biological impairment in Kits Creek was based on an evaluation of candidate stressors that potentially impact the creek. These candidate stressors include dissolved oxygen, temperature, pH, instream water chemistry (nutrients, dissolved metals), sediment chemistry (metals, insecticides, pesticides), and sedimentation. Each stressor was classified as one of the following:

Non-stressor: Stressor with data indicating normal conditions, without water quality standard exceedances, or without any apparent impact.

Possible stressor: Stressor with data indicating possible links to the benthic impairment, but without conclusive data to show a direct impact on the benthic community.

Most probable stressor: Stressor with conclusive data linking the stressor to the poor health of the benthic community.

Table 4-1 summarizes the results of the stressor identification for Kits Creek.

Table 4-1: Summary of Stressor Identification in Kits Creek
Non-Stressor(s)
Dissolved Oxygen
pH
Temperature
Instream Dissolved Heavy Metals
Sediment Heavy Metals
Sediment Organic Compounds
Possible Stressor
Total Nitrogen
Most Probable Stressors
Total Phosphorus
Sedimentation

4.1 Non-Stressors

The following parameters do not appear to be adversely impacting benthic communities in Kits Creek and are therefore classified as a non-stressor.

4.1.1 Dissolved Oxygen

Benthic macroinvertebrates and other aquatic organisms require a suitable range of dissolved oxygen conditions to survive close to or within the benthic sediments of rivers or streams. Decreases in instream oxygen levels can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. None of the dissolved oxygen measurements exceeded VADEQ's minimum criterion of 4.0 mg/L (SWCB, 2011).

4.1.2 pH

Benthic macroinvertebrates require a suitable range of pH conditions. Although these ranges may vary by invertebrate phylogeny, very high or very low pH values may result in a poor invertebrate assemblage comprised predominantly of tolerant organisms. The Virginia Class III water quality standards identify the acceptable pH for Kits Creek (6.0 – 9.0) (SWCB, 2011). All of the samples fell within the water quality standard range.

4.1.3 Temperature

Benthic macroinvertebrates require a suitable range of temperature conditions to survive in streams and rivers. High instream temperature values may result in an impaired invertebrate assemblage comprised predominantly of pollution-tolerant organisms. All temperature measured in Kits Creek were below the maximum temperature criterion of 32°C (SWCB, 2011).

4.1.4 Instream Heavy Metals

All available dissolved metals data (arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc) were below the acute and chronic dissolved freshwater criteria specified in Virginia's aquatic life use standards (SWCB, 2011).

4.1.5 Sediment Heavy Metals

Metals in sediment were analyzed to determine whether they complied with the screening values known as Probable Effects Concentrations (PECs) for freshwater (VADEQ, 2013) None of the metals measured in sediment samples (arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc) exceeded the respective PEC value.

4.1.6 Sediment Organic Compounds

Virginia does not have water quality standards for sediment organic compounds, but some of the organic compounds do have PECs which are outlined in the probabilistic monitoring chapter of the 2012 Integrated Assessment (VADEQ, 2013). None of the organic compounds (insecticides and pesticides) with PECs which were analyzed in the sediment samples (chlordane, dieldrin, endrin, guthlindane, and heptachlor) exceeded the respective PEC value.

4.2 Possible Stressor

4.2.1 Nitrogen

Elevated nitrogen concentrations can stimulate algal growth that may result in eutrophic conditions, high organic loading, and decreased dissolved oxygen levels in the early morning hours of the growing season. Excessive periphyton growth can impact the benthic macroinvertebrates present in the stream, causing some trophic groups to decline and others to increase in population. Increased periphyton growth prevents benthic macroinvertebrates from attaching to substrate, and the kinds of algae typically associated with eutrophication are undesirable sources of food (Voshell, 2002). In Kits Creek, total nitrogen (TN) concentrations were elevated at the upstream monitoring station (5AKIT002.65), but lower at the downstream station (5AKIT000.67). The average TN concentration at station 5AKIT002.65 was 1.51 mg/L (median of 0.75 mg/L) and 0.40 mg/L (median of 0.32 mg/L) at station 5AKIT000.67.

Through its probabilistic statewide stream monitoring program, VADEQ (2013) developed a risk scale based on nutrient concentrations and their potential for impacting benthic macroinvertebrate communities (via VSCI scores). **Table 4-2** presents the risk categories based on their potential to impact VSCI scores and the corresponding TN ranges. VADEQ (2013) concluded that TN concentrations exceeding 2 mg/L indicate a high probability that VSCI scores will not pass the minimum attainment threshold of 60.

Table 4-2: VADEQ Total Nitrogen Risk Scale [1]

Risk Category	Total Nitrogen (mg/L)
Suboptimal Risk to Aquatic Life	>2.0
Optimal Risk to Aquatic Life	<1.0

[1] The risk scale values presented in Tables 4-2 do not represent nutrient criteria nor are intended for establishing TMDL endpoints. This is a risk assessment tool presented in Virginia's 2012 Integrated Report and is used in conjunction with an existing impairment. The values are thought to represent an increase in probability of impairment.

Using the TN risk scale, the average TN concentration at upstream station 5AKIT002.65 was between the suboptimal and optimal risk to aquatic life categories, but the median concentration was in the optimal risk to aquatic life category. The elevated average was a result of two samples that had TN concentrations of greater than 3 mg/L, indicating that TN could contribute to the VSCI scores not attaining the threshold of 60.

At downstream station 5AKIT000.67, both the average and median concentrations were in the optimal risk to aquatic life category. Because TN values were elevated at the upstream station but recovered by the downstream station, TN was identified as a possible stressor to the benthic community.

4.3 Most Probable Stressors

4.3.1 Phosphorus

Increased phosphorus concentrations can stimulate algal growth that may result in eutrophic conditions, high organic loading, and decreased dissolved oxygen concentrations in the early morning hours of the growing season. Excessive periphyton growth can impact the benthic macroinvertebrates present in the stream, causing some trophic groups to decline and others to increase in population. Increased periphyton growth prevents benthic macroinvertebrates from attaching to substrate, and the kinds of algae typically associated with eutrophication are undesirable sources of food (Voshell, 2002). In Kits Creek, total phosphorus (TP) concentrations were elevated at upstream station 5AKIT002.65, but lower at downstream station 5AKIT000.67. The average TP concentration at station 5AKIT002.65 was 0.15 mg/L (median of 0.13 mg/L) and 0.05 mg/L (median of 0.04 mg/L) at station 5AKIT000.67.

VADEQ (2013) also developed a risk scale based for TP. **Table 4-3** presents the risk categories based on their potential to impact VSCI scores and the corresponding TP ranges. In essence, VADEQ (2013) concluded that TP concentrations exceeding 0.05 mg/L indicate a high probability that the VSCI score will not pass the minimum attainment threshold of 60.

Table 4-3: VADEQ Total Phosphorus Risk Scale[1]

Risk Category	Total Phosphorus (mg/L)
Suboptimal Risk to Aquatic Life	>0.05
Optimal Risk to Aquatic Life	<0.02

[1] The risk scale values presented in Tables 4-3 do not represent nutrient criteria nor are intended for establishing TMDL endpoints. This is a risk assessment tool presented in Virginia's 2012 Integrated Report and is used in conjunction with an existing impairment. The values are thought to represent an increase in probability of impairment.

Using the TP risk scale, it was found that all TP concentrations were greater than 0.05 mg/L at station 5AKIT002.65, placing them in the suboptimal risk to aquatic life category for TP and indicating that TP is contributing to the VSCI scores not attaining the threshold of 60.

In addition, and as discussed in Section 3.3 above, epifaunal substrate scores were consistently low at station 5AKIT002.65, indicating a lack of natural habitat for aquatic microfauna. This is also an indication of excessive algae growth, potentially caused by the higher than normal TP concentrations. Therefore, TP was identified as a probable stressor to the benthic community.

4.3.2 Sedimentation

Sedimentation reduces the available habitat for sensitive benthic macroinvertebrates and can cause the community to become impaired. The habitat scores measured in Kits Creek for sedimentation were low (sampled at station 5AKIT002.65). Runoff from the agricultural and forested lands and the decrease in bank stabilization cause instream erosion, which contribute to the sediment load within the stream and can lead to increased sediment deposition and embeddedness. Chapter 3 describes that, on average, the bank stability, sediment deposition, and embeddedness scores are consistently suboptimal; which indicates that streambed sedimentation is degrading the benthic community.

Additionally, the soil survey in Lunenburg County (NRCS, 2006) identified 88% of the soil composition in the Kits Creek watershed as "eroded". The soil survey also identified 47% of the soil composition in the watershed as having a moderate potential erosional hazard from forest roads and trails, and 47% of the soil composition in the watershed as having a severe potential erosional hazard from forest roads and trails. The soil survey data indicate a strong probability for soil erosion in Kits Creek.

In addition to the habitat data indicating elevated sedimentation in Kits Creek, there are qualitative observations from monitoring staff which could indicate sediment is a probable stressor to the Kits Creek benthic community. VADEQ staff visited station 5AKIT000.67 in July of 2015 and documented the streambed sedimentation and instream sediment load of Kits Creek. **Figure 4-1** shows a moderate quantity of suspended solids within the stream.

Figure 4-1: Kits Creek mainstem directly below bridge at Station 5AKIT000.67 .

In addition to the observed instream sediment load, there was a preliminary attempt to identify sources of sediment to Kits Creek. Through aerial imagery, it was observed that there is forest harvesting occurring in the watershed. When forest harvesting occurs, typically a forest stand is clear cut, leaving the cut area exposed. Subsequent rain storms may erode the exposed soil and transports it to the stream where it may adversely affect the benthic community. **Figure 4-2** shows an example of clear cut forest harvesting in the Kits Creek watershed (July 2015).

Figure 4-2: Forest Clear Cutting in Kits Creek Watershed.

Due to the low habitat scores in regards to sediment at the habitat monitoring station in Kits Creek, the erosion potential for soil in Kits Creek, and the qualitative evidence of stream erosion and sediment supply, sedimentation is considered a probable stressor to the benthic community of Kits Creek.

4.4 Stressor Identification Summary

The data and analysis presented in this report indicate that dissolved oxygen, pH, temperature, instream and sediment heavy metals, and sediment organic compounds in the biologically impaired segment of Kits Creek are adequate to support a healthy invertebrate community, and are not stressors contributing to the benthic impairment.

Total nitrogen was determined to be a possible stressor because some concentrations exceeded the nutrient threshold guidelines outlined in the probabilistic monitoring chapter of the 2012 Integrated Assessment (VADEQ, 2013), but the average and median concentrations were in generally in the optimal risk to aquatic life category.

Typically, high levels of periphyton and nutrients cause eutrophication in waterbodies, and an indicator of eutrophication is hypoxia, or the depletion of DO in water. Although measured DO concentrations were above the minimum criterion of 4.0 mg/L, TP concentrations were consistently high at all monitoring stations in Kits Creek and were in the suboptimal risk to aquatic life category for phosphorus as outlined in the probabilistic monitoring chapter of the 2012 Integrated Assessment (VADEQ, 2013).

The lack of eutrophication evidence indicates that while phosphorus is considered a stressor to the benthic community, there is likely an additional stressor, sediment, causing degradation in the benthic community. There is strong evidence (low habitat scores, erosional potential of the soil, and qualitative observations) for sedimentation causing degradation to the benthic community.

Therefore, both phosphorus and sedimentation were selected as probable stressors, suggesting that Total Maximum Daily Loads should to be developed for these two parameters to address the benthic impairment in Kits Creek.

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